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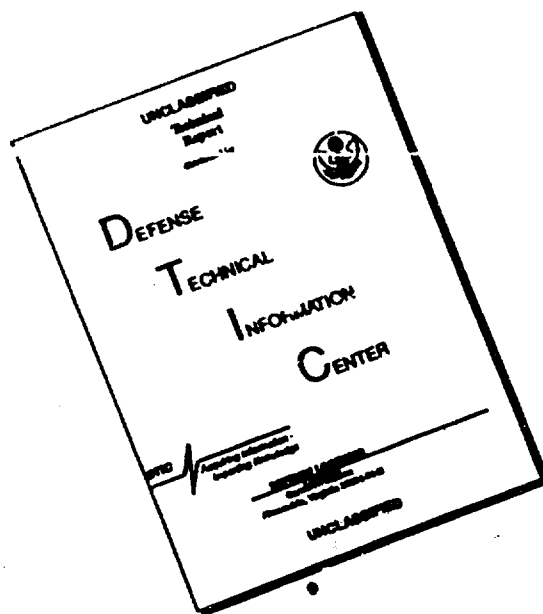
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13. ABSTRACT (Maximum 200 words) The 1991 Gordon Research Conference on Physical Metallurgy was held July 29-August 2, 1991 at the Plymouth College South location in Plymouth, New Hampshire. The Conference topic was Foundations of Microstructure Development. The study of microstructural development in metals and alloys is a cornerstone of physical metallurgy. From an understanding of the compositional, thermodynamic and kinetic constraints, new levels of control and the development of new microstructures may be possible. The discussion was organized to present state-of-the-art developments in such keynote issues as alloy phase stability, crystal growth and solidification, diffusion in ordered alloys and multicomponent systems, interfacial structure and phase decomposition kinetics. There was a balanced coverage between theoretical and modeling analysis and critical experimental work involving verification tests and applications. In addition, an industrial perspective in the areas of aluminum alloys, aerospace materials and electronic materials was included in the program. In light of the vigorous discussion during the conference the foundations of microstructural development clearly generated a keen interest. Several emerging new issues in alloy phase stability, in crystal growth and solidification, diffusional reactions, interfacial structure and phase decomposition were highlighted during the meeting. Equally important is the industrial perspective that allowed for the often pointed out gap between theoretical and experimental developments and industrial applications to be bridged to some extent. New perspectives and new interactions were developed at the meeting which will yield future dividends.			
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FINAL REPORT

AFOSR Grant (AFOSR-91-0173) for the Support of the 1991 Gordon
Conference on Physical Metallurgy

"Foundations of Microstructure Development"

Submitted to

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Introduction

The 1991 Gordon Research Conference on Physical Metallurgy was held July 29-August 2, 1991 at the Plymouth College South location in Plymouth, New Hampshire. The Conference topic was Foundations of Microstructure Development. US Government grants were made to the Gordon Research Conference to offset partially the travel and registration cost of many the speakers and discussion leaders, a few attendees, and the co-chairman. Grants totaled \$18,000.00. Of this total, \$6,000.00 each was provided by AFOSR (AFOSR-91-0173), ONR and NSF (DMR-9102779). In this final report a brief description of the conference is given and includes some of the highlights of the meeting and discussions.

Conference Description

The study of microstructural development in metals and alloys is a cornerstone of physical metallurgy. An effective approach to this theme can be developed by examining the limiting bounds for a given microstructural type. From an understanding of the compositional, thermodynamic and kinetic constraints, new levels of control and the development of new microstructures may be possible. As a result, the conference program was focused on the critical processes governing microstructural development. The discussion was organized to present state-of-the art developments in such keynote issues as alloy phase stability, crystal growth and solidification, diffusion in ordered alloys and multicomponent systems, interfacial structure and phase

decomposition kinetics. There was a balanced coverage between theoretical and modeling analysis and critical experimental work involving verification tests and applications.

The conference program was organized on the basis of the realization that major advances in physical metallurgy leading to novel insight or new discoveries have often occurred as a result of a steady, concerted study effort on an experimental and theoretical front to examine fundamental physical processes. Often the discoveries appear as anomalies, but with further examination the anomaly becomes recognized as a new aspect of a basic mechanism. In addition, there is an important realization that much of the work in the physical metallurgy of advanced materials is intended for eventual applications. As a result, the initial session of the first day provided that perspective in the areas of aluminum alloys, aerospace materials, and electronic materials. This was followed by a session on interface reactions where the theoretical and experimental developments including the latest studies were described. Since most metals undergo a melting and solidification process sometime during their fabrication, the importance of crystal growth and solidification is apparent and occupied most of the discussion of the second day. Similarly, the basis of materials processing is rooted in diffusional transformations which was the basic theme of the third day where the discussion ranged from the very early stages of precipitation to multicomponent systems and basic mechanisms of diffusion in more complex systems. This discussion carried over to the fourth day with some of the detailed studies of

interface structure including the effects of elastic stresses. Finally, the program ended with discussion of ordering reactions and displacive transformation that are becoming recognized as crucial in many of the latest developments in transformation kinetics.

While every effort was made to identify frontier issues with each of the foundation topics, it was recognized that such a listing can not be completely comprehensive and still allow time for the extensive discussion that is the hallmark of a successful Gordon Conference. Certainly, further issues and perspectives were brought out in the discussion. However, each of the foundation topics could be a theme of a separate conference. Indeed one of the advantages of the Gordon Conference forum is the ability to bring together various groups and perspectives to have a high level exchange of experimental and theoretical developments.

Following the tradition of previous Gordon Conferences, a relatively small number of speakers were invited to make presentations to the conference. The main purpose of these talks was to describe recent progress and set the stage for further thought and discussion. A copy of the program and speakers and discussion leaders is appended to this report. In addition, a poster session was also held during the conference in order to allow some of the participants to present their research results. This was a well attended session with over 20 contributed

posters, provided a basis for broad exposure of very new results and stimulated a great deal of excitement that are often continued late into the evening.

The conference attracted participants from a wide variety of institutions and backgrounds. A list of attendees appended to this report shows that a total of 124 scientists and engineers participated in the conference. Of these only 31 were on the program as speakers and discussion leaders. The attendees included 106 from the United States and 18 from foreign countries. Of these 68 were from universities, 37 from government laboratories or offices and 19 from industry. Finally it is worth noting that the number of applicants for this conference exceeded the number of places available.

Program Highlights

The major attraction at Gordon Conferences is the opportunity to interact on an informal level with a large number of scientists interested and knowledgeable in a given subject. Facilities at the Plymouth College catered to this aspect in a number of ways; the main lounge, the game room, and the grounds were excellent sites for informal discussion. These facilities were in use throughout the day and night for numerous small group discussions which led to the development of research ideas and interactions. This informal aspect of the Gordon Conference, was therefore a success.

In the formal program the initial session provided an industrial perspective on advanced materials. For example, Staley from Alcoa discussed aluminum alloy development and as

requested raised a number of issues for future work including how the grain size is limited by a various particles in aluminum alloys, some new areas in presolidification processing to initiate particulate formation, and the need for additives in aluminum alloys to remove undesirable impurities. In a similar vein Blackburn from Pratt & Whitney discussed the importance of modeling in scaling-up processing from laboratory operations to production operations. He also pointed out that the best property in any given category cannot usually be obtained in the best combination of properties and as a result process models are essential to allow for an optimum balance of properties. Rosenberg from IBM provided information on many exciting developments in the miniaturization of electronic circuits down to 0.1 microns in scale. Devices have been made in the laboratory, but again the point was made on how to scale-up the processing. He pointed out that more than 98% of system failures are related to metallization treatments and that this issue provides a wealth of important problems to deal with. Next, John Cahn provided an informative discussion of heterogeneous nucleation along the lines of Gibbs including very interesting new developments in wetting behavior and crystal morphologies. This discussion was complemented very nicely by Dahmen who provided some outstanding TEM micrographs to illustrate the development of crystal morphology at the atomic scale. The next day was devoted to solidification. Trivedi gave an overview of some of the unsolved problems in solidification microstructure development. He also provided useful insight into the

understanding of study state processes and the development of microstructure over a range of velocity. Brown followed this with a more focused discussion on wavelength selection during cellular solidification where the complete domain of velocity-wavelength behavior is being mapped out including the important onset ranges of breakdown of planar interface and the various time scales appropriate for the different breakdown behavior. Dantzig gave summary of the modeling approaches to process development ranging from nucleation kinetics models, which are sorely lacking to approaches for accounting for growth kinetics and heat evolution during solidification. The evening session belonged to the theoreticians. Sekerka provided very effective introduction to the main theoretical developments in diffuse interface theories of crystal growth and phase field calculations of solidification. These are two approaches to deal the difficulties of matching solutions in the liquid and solid state at the interface. In the diffuse interface model Oxtoby described perturbation approaches where the liquid is treated as a perturbed solid and the solid treated as a perturbed liquid as a means of modeling their behavior. Wheeler approached the problem from phase field model method which deals with the existence of various potentials which are expressed in terms of an order parameter. While each approach has advantages, it is not clear at present which is superior. They both appear to give effective descriptions of observed behavior. Clearly more development of analysis is needed. On the third day Cohen provided an excellent overview of the early stages of

participation including the formation of GP zones, initially ordered configurations and clustering effects where strain energy factors become important. This is followed Purdy's discussion of precipitation in ternary systems where the concept of local equilibrium sometimes needs to be modified to include paraequilibrium i.e. equilibrium with respect to one component. The morning ended with a discussion by Greer of recent developments in solid state amorphization during interdiffusion reactions. The various thermodynamic and kinetic behaviors were analyzed including how to treat diffusion in the very steep concentration gradients that develop in multilayer structures at the onset of interdiffusion which is a new realization.

These discussions were followed in the evening by a presentation on diffusion in ordered alloys by Bakker who pointed out that there is a much stronger correlation factor in ordered crystals than in disordered crystals and that one must consider defect structures on the sublattices in ordered crystals. For example, when this is done in Ni_3Al , it is found that nickel can diffuse on its own sublattice at much the same rate as for self diffusion in pure nickel. Van Loo presented an elegant discussion of the Kirkendall effect during multiphase diffusion. He described methods to analyze diffusion path sequences in multicomponent systems which is crucial in the development of composite structures. The importance of interfaces and domain structures that develop in elastically strained systems was the highlight in the next session. Howe presented video images of lattice resolution TEM studies conducted at high temperature to

reveal the dynamics of interface motion. This is truly a remarkable experimental achievement. Voorhees discussed an interesting analysis of the competition between strain energy and interfacial energy in determining the equilibrium shape of a precipitate in the later stages of reaction. Roytburd followed with a detailed analysis of the formation and development of polydomain structures that often occur in twinning and martensite reactions and involve multiple subdivision with the development of increasing levels of elastic strain. The last two sessions dealt with various aspects of the thermodynamics and kinetics of ordering reactions. Inden gave an informative overview of phase diagram modeling starting from the regular solution all the way up to cluster variation methods that are used to treat more complex interactions. This is followed by Allen's analysis of the behavior of diffuse interfaces with respect to order parameter as well as concentration gradients. He applied this analysis to explain some of the domain coarsening kinetics observed in ordered alloy. In a detailed study of the kinetics of ordering reactions, Banerjee highlighted some of the crystallographic aspects. Often BCC phases develop transformations by various shears of (110) planes. In the last presentation Johnson tried to integrate the diffusive and displacive characteristics of transformations. It is becoming clear that both aspects can occur in given transformation types and that the traditional distinction between displacive and diffusional transformations is not as sharp as it has been viewed previously. As a sign of the interest and animated discussion

during the conference, it is useful to point out that more than 85 people were on hand to hear the last presentation on Friday morning.

In light of the vigorous discussion, the foundations of microstructural development clearly generated a keen interest. Several emerging new issues in alloy phase stability, in crystal growth and solidification, diffusional reactions, interfacial structure and phase decomposition were highlighted during the meeting. Equally important is the industrial perspective that allowed for the often pointed out gap between theoretical and experimental developments and industrial applications to be bridged to some extent. New perspectives and new interactions were developed at the meeting which will yield future dividends.

Physical Metallurgy
Gordon Conference
Plymouth State College (South), Plymouth, NH
July 29 - August 2, 1991

William J. Boettinger and John H. Perepezko, Cochairmen
Anthony W. Thompson and Robert O. Ritchie, Vice-Chairmen

1991 Conference Topic
Foundations of Microstructure Development

Morning sessions start at 8:30 AM

Evening sessions start at 7:30 PM

Monday AM: Industrial Perspective on Advanced Materials (Alan Rosenstein, AFOSR)

James Staley, Alcoa	Al Alloy Development
Martin Blackburn, Pratt & Whitney	Advanced Aerospace Alloys
Robert Rosenberg, IBM	Electronic Materials

Monday PM: Interface Reactions (Frans Spaepen, Harvard)

John Cahn, NIST	Heterogeneous Nucleation
Ulrich Dahmen, Lawrence Berkeley Lab.	TEM Study of the Development of Grain Boundaries & Precipitates

Tuesday AM: Solidification Microstructures (John Hunt, U. of Oxford)

Rohit Trivedi, Iowa State U.	Solidification Microstructures
Robert Brown, MIT	Nonlinear Dynamics & Wavelength Selection in Cellular Solidification
Jonathan Dantzig, U. of Illinois-Urbana	Macro/Micromodelling of Eutectic Castings

Tuesday PM: Crystal Growth Kinetics (Bob Sekerka, Carnegie-Mellon)

David Oxtoby, U. of Chicago	Diffuse Interface Theories of Crystal Growth
Adam Wheeler, U. of Bristol	Phase Field Calculations of Binary Alloy Solidification

Wednesday AM: Diffusional Transformations (Bill Morris, UC-Berkeley)

Jerry Cohen, Northwestern U.	Early Stages of Precipitation
Gary Purdy, McMaster U.	Precipitation in Ternary Systems
Lindsay Greer, U. of Cambridge	Solid-State Amorphization

Wednesday PM: Diffusion Mechanisms (John Morral, U. Conn.)

Hans Bakker, U. Amsterdam	Diffusion Mechanisms in Ordered Intermetallics
Frans van Loo, Eindhoven U.	Kirkendall Effect in Multiphase Diffusion

Thursday AM: Interfaces & Domains (Caroi Handwerker, NIST)

Jim Howe, U. of Virginia

Peter Voorhees, Northwestern U.

Alexander Roytburd, U. of Maryland

HRTEM of Interfaces

Dynamics of Interfaces in Elastically Stressed
Solids

Formation of Polydomain Structures

Thursday PM: Ordering Transformations (Ben Burton, NIST)

Gerhard Inden, Max Planck Inst.
Eisenforschung

Sam Allen, MIT

Phase diagram Modeling

Diffuse Interfaces in Ordering Systems

Friday AM: Displacive Transformations (Lee Tanner, Lawrence Livermore)

Srikumar Banerjee, Bhabha Atomic
Research Centre, Bombay, India

Bill Johnson, Carnegie-Mellon

Replacive/Displacive Ordering

Transformations Displaying Diffusive and
Displacive Characteristics

GORDON RESEARCH CONFERENCE
Physical Metallurgy

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